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STRUCTURAL TESTS OF PLASTIC FRANGIBLE COUPLINGS.(U)
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STRUCTURAL TESTS OF PLASTIC FRANGIBLE COUPLINGS

Bret B. Castle

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JANUARY 1977

FINAL REPORT

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16. Abstract

Tests were conducted on standard frangible couplings and a type of plastic frangible couplings to determine if they were equal to the specified requirements as far as resonant frequency, static loads, and impact loads were concerned. Results indicated that standard metal couplings were congruent with frangibility requirements, but the plastic couplings were not. Under static loads, the plastic units showed excessive bending and, when broken, failed to shear away cleanly. Impact testing indicated that the plastic couplings were much too sinewy to meet the frangibility standards presently required of the standard couplings. Additional considerations in selection of a material for frangible couplings should also include temperature, electrical conductivity, and fatigue factors, none of which were covered in the present test series.

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METRIC CONVERSION FACTORS

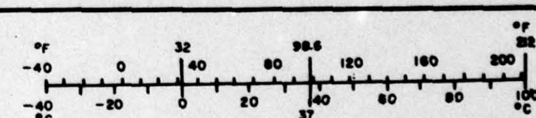
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

The purpose of this evaluation is to determine whether a type of plastic frangible coupling furnished by the United States Air Force meets the frangibility requirements of the Federal Aviation Administration (FAA) standard metal-type frangible coupling.

BACKGROUND.

Frangible couplings are designed to break at low impact forces, thereby reducing severe aircraft damage and fatalities in case of a collision with visual aid structures. These couplings have been used for years to increase the safety factor wherever accidental collisions can occur. Studies have been made in an effort to design a more frangible support structure; however, to date, these structures are not readily available. Now and then, new designs of frangible couplings are developed which must be evaluated to determine whether they are frangible under trying conditions, and yet perform their proper function under normal environmental airport conditions. This report presents results of resonant frequency tests, static load tests, impact load tests and fatigue tests performed on standard frangible couplings and on plastic frangible couplings. These tests were to be continued until conclusive evidence proved that the plastic frangible couplings were or were not equal to the present standard aluminum frangible couplings.

DISCUSSION

EQUIPMENT DESCRIPTION.

The plastic frangible couplings came into being because the Air Force found that when the standard aluminum couplings broke, as they should, it was difficult to remove the threaded portion from the base due to the corrosive action of the aluminum. They found that this problem was eliminated by using plastic couplings of the same general shape and dimensions. They, therefore, asked the FAA to test the plastic couplings for frangibility. The FAA prevents this problem by use of a lubricant on the threads.

TEST PROCEDURES.

All tests were performed in the Environmental Laboratory of the National Aviation Facilities Experimental Center (NAFEC). The test procedures on both types of frangible couplings (figure 1), conformed as nearly as possible to the present-day specification requirements in the drawings, handbooks, and Advisory Circulars that were applicable. The plastic frangible couplings made it impossible to conform entirely with all specification procedures, and it was necessary to provide an interface coupling (figure 2), between the frangible

coupling and the electrical metallic tubing (EMT) that is used with approach lights. It is believed that the Air Force did not use this type frangible coupling except on the runway edge, threshold, or on very low elevated approach lights; therefore, mating of a plastic frangible coupling to the EMT was not required.

Simultaneous tests were made on standard FAA aluminum frangible couplings and on the plastic couplings, in order to obtain comparison test data.

RESONANT FREQUENCY TEST. This test was made to determine the natural frequency at which the supports would vibrate during high winds, causing fatigue failures and to establish a standard on which to base other tests. A 4-foot PAR-56 lamp assembly was chosen for these tests. This was considered typical for present-day and future-trend assemblies and yet of a size that could be handled reasonably well in a laboratory to obtain standard measurements. The assembly consisted of a base plate, the particular frangible coupling under test, sufficient EMT to measure 4 feet from the top of the base plate to the center of the PAR-56 lamp, the lamp holder, and matching cable running down inside the length of the EMT to the base plate (figure 3).

A number of different data recording schemes were tried in an effort to determine the resonant or natural frequency of the above assembly, including the use of an electromechanical vibration shaker system. Analysis determined that the shaker system available at NAFEC was not capable of providing the test parameters for a fixture of this magnitude. The best results were obtained by anchoring the base plate firmly and vibrating the lamp assembly by simply plucking it near the lamp holder. Vibration sensors located on the assembly transferred the oscillations to a recording oscilloscope. A General Radio Vibration Pickup, type No. 1560-P52, sensed the vibrations, which were compared with the output of a calibrated Hewlett-Packard Model 202A function generator. Oscilloscope pictures which were obtained by use of a Tektronix 7623 storage oscilloscope and a C-50 Tektronix camera are presented under test results.

STATIC TESTS. Advisory Circular 150/5345-48, entitled "Specification for Runway and Taxiway Edge Lights" and dated August 1, 1975, calls for the frangible coupling to have a "shearing groove" produced by scoring, molding, etc., which will withstand a static load of 300 pounds (lb) with less than 1/2-inch deflection when the load is applied perpendicular to the axis of the coupling, at a point 12 inches above the shearing groove. Further, the coupling is required to break cleanly at the groove when the static load reaches 500 lb. The Advisory Circular also states that the manufacturer shall furnish certified test reports attesting to meeting the above requirements, and that all tests of the breakable fittings shall be performed with the fittings screwed tightly in place in a base plate or stake fitting, and with the base plate or stake fitting securely bolted to a firm and rigid foundation. Further, for testing there shall be inserted in the breakable fitting, a 16-inch length of round aluminum rod, suitably turned down at one end to fit tightly in the breakable fitting. The load shall be applied no faster than 50 lb per minute, and must continue to be applied until the fitting breaks. It is required to test and break five

fittings and use the average results obtained in determining the static load tests. The average breaking strength shall not exceed 400 lb, for medium- and low-intensity lights, and 500 lb for high-intensity lights.

A test jig was fabricated that would satisfy the above requirements, including a 16-inch length of round aluminum rod (figure 4), suitably turned down at one end to fit tightly into the frangible coupling. The test setup is shown in figures 5 and 6. Because the plastic frangible couplings were 3 3/4 inches long, without a shearing groove, two possible solutions were (1) to either clamp the holding rod around the plastic frangible coupling, or (2) to turn down one end of the holding rod so that it would extend into the frangible coupling approximately half way.

The holding rod for the plastic frangible coupling was made with a 2-inch fitting on one end designed to encompass and hold the frangible coupling utilizing six screws. The other end was turned down in such a manner that it fit tightly inside the frangible coupling for a distance of 2 inches. The straight rod for the standard frangible coupling weighed 6 lb 9/16 ounces (oz), and the double-ended rod for the plastic frangible coupling weighed 6 lb 7 3/8 oz.

Static tests were conducted using a Riehle tension/compression tester, model FS-5, Universal Precision Screw Power Testing Machine, serial No. R-91474, with a capacity of 5,000 lb force (figure 7). This Riehle tester easily met the conditions necessary for this evaluation. Static load tests were run on both the standard aluminum frangible coupling and the plastic frangible coupling during May and June 1976. The results are shown in table 1.

IMPACT TESTS. FAA drawing B-4904B, entitled "Frangible Coupling, Type 1 and Type 1A, Details" and dated June 18, 1971, calls for the depth of the frangible groove to be adjusted so that it will stand an impact load of 20 foot-pounds (ft-lb) applied 12 inches from the cut and will break at a 30 ft-lb impact. A test jig was fabricated in such a manner that an impact load of the proper weight could be applied 12 inches from the designed breaking point (figures 8 and 9). A weight-holding platform was hung from this point on an aluminum rod leading to the frangible coupling which was held firmly in a horizontal position. The proper impact weight (e.g., 20 lb) was allowed to fall 1 foot onto the weight-holding platform, thereby creating the proper impact load (figures 10 and 11).

The results of the impact tests on six of the standard FAA couplings and three of the plastic couplings are tabulated and presented in table 2.

TEST RESULTS.

RESONANT FREQUENCY TEST. No specification value was required to be met in this test. The results indicated that the standard 4-foot PAR-56 lamp assembly with the standard frangible coupling had a resonant or natural frequency of 16.5 hertz, and the 4-foot PAR-56 lamp assembly, including a plastic frangible and interface coupling, had a resonant or natural frequency of 6 hertz. Oscilloscope pictures of the typical oscillations were taken, and the results

TABLE 1. STATIC TESTS

FAA STANDARD FRANGIBLE COUPLING			PLASTIC FRANGIBLE COUPLING		
Standard Unit No.	(Pounds) Breaking Static Load	(Inches) Total Deflection	Plastic Unit No.	(Pounds) Breaking Static Load	(Inches) Total Deflecction
1	570	0.25	1	263	1 3/4
2	558	.19	2	263	1 3/4
3	554	.19	3	325	4
4	433	.13	4	280	2 1/16
5	589	.19	5	302	2 1/4

TABLE 2. IMPACT TESTS

FAA STANDARD FRANGIBLE COUPLING

Test No.	Standard Unit No.	Results (Ft-Lb) No Breakage	Results (Ft-Lb) Broke
1	1		30
2	2		20
3	3	10	
4	3		20
5	4		20
6	5	10	
7	5		15
8	6	15	
9	6	15	
10	6		20

PLASTIC FRANGIBLE COUPLING

Test No.	Plastic Unit No.	Results (Ft-Lb) No Breakage	Results (Ft-Lb) Broke
11	1	20	No Breakage During Any Test
12	1	30	
13	1	35	
14	1	40	
15	1	45	
16	1	50	
17	2	20	
18	2	30	
19	2	40	
20	2	50	
21	2	60	
22	2	75	
23	3	50	
24	3	75	

are shown in figure 12. A comparison of the photographs shows the difference in amplitude, ringing, and frequency between the assembly with the standard aluminum coupling (figure 12A, B, and C) and with the plastic coupling (figure 12D, E, and F). Figures 12A and D show the damped oscillations of the assemblies with the standard frangible coupling and with the plastic frangible coupling, respectively. Figure 12B and E show blown-up center sections of figure 12A and D, respectively, while figure 12C and F compare the natural frequencies with the input of the frequency generator. In figure 12C, the calibrated frequency is the small (2 centimeters) sine wave at 16.5 hertz, and the large sine wave is the oscillations of the lamp assembly. In figure 12F the calibrated frequency is the lower sine wave at 6 hertz, and the upper waveform is the oscillations of the lamp assembly. The plastic frangible coupling produced a more damped oscillation and a lower natural frequency than did the standard aluminum frangible coupling.

STATIC TESTS. As seen by the tabulated results presented in table 1, the standard FAA frangible coupling broke cleanly at static load values from 433 to 589 lb. The average of 540 lb is within 10 percent of the allowable 500 lb. The deflection was measured 12 inches from the probable breaking point and varied from 0.13 to 0.25 inch; thus, the average of 0.19 inch at that point is well within the requirement of 1/2 inch. Figure 13 shows the appearance of the broken couplings.

The results of the static load tests on the plastic frangible coupling are also listed in table 1. In order to keep the tests as comparable as possible, the test rod that fitted snugly inside the plastic frangible coupling was used. These units broke under loads from 263 to 325 lb, with an average load of 287 lb, which is within 5 percent of the 300-lb minimum load required by the Advisory Circular.

Results show that although the couplings were designed to break, one plastic frangible coupling never broke at the maximum deflection on the test jig of 4 inches, and simply deflected the 4 inches without breaking. The plastic couplings did not break clean, as did the standard aluminum couplings, but began to fracture near the base plate leaving half of the coupling intact. During the static tests, the deflection of the plastic couplings varied from 1-3/4 inches to 4 inches, with an average of approximately 2.36 inches for the five units. This deflection far exceeds the 1/2-inch requirement for the 12-inch load point.

IMPACT TESTS. These tests were the most important, in that they were close to true-life events, such as the impact of an aircraft into approach lights. A total of six standard frangible couplings and three plastic frangible couplings were subjected to these tests (figure 14).

The FAA drawing specifies an impact at which the frangible coupling will not break, as well as an impact at which it will break. As the weights used were in 5-lb steps, the accuracy was also in 5-lb increments. The results of both the standard frangible coupling and plastic frangible coupling are shown in table 2.

Of the six standard metal frangible couplings tested, three had both a "no-break" and a "break" figure. Unit No. 3 did not break at 10 ft-lb but broke at 20 ft-lb; unit No. 5 did not break at 10 ft-lb but broke at 15 ft-lb; while unit No. 6 did not break at 15 ft-lb but broke at 20 ft-lb impact. From this one might conclude an average no-break point of 15 ft-lb impact. The lowest figure at which the standard frangible coupling broke was 15 ft-lb and the highest figure was 30 ft-lb impact. The average of the breakpoints was 20.8 ft-lb, which is within the allowable specification.

The plastic frangible coupling impact tests resulted in no breakage at all. Three units were tested. The first unit was tested from 20 ft-lb up to 50 ft-lb; the second was tested from 20 ft-lb up to 75 ft-lb; and the third was tested at 50 ft-lb and 75 ft-lb impacts. The tests were halted at this point, as there was no indication that the impact breaking point would be anywhere near the maximum of 30 ft-lb called for in the drawing.

GENERAL.

All tests were conducted in an ambient temperature around 70° Fahrenheit (F). A point to consider is that deflections of the plastic couplings under static load and fracture load limits may be affected by temperature, since materials in this class are believed to be more sensitive to heat and cold than are most metals. Additional tests would be required to evaluate the significance of the temperature factor, as well as the question of maintenance personnel hazard due to electrical insulation properties. Grounding of all equipment supported by nonconducting (plastic) materials is necessary as a safety precaution.

CONCLUSIONS

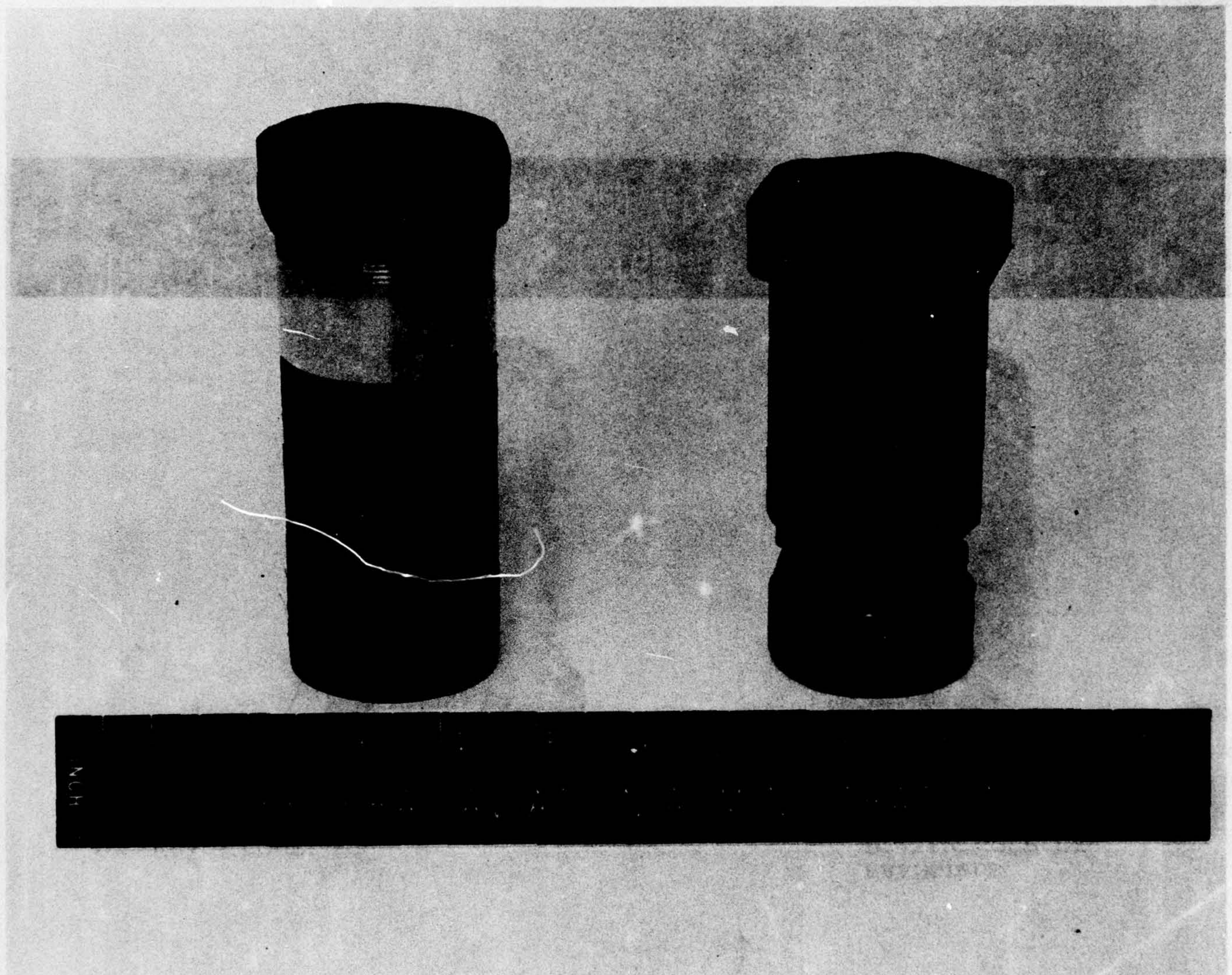
Based on the outcome of the tests performed, it is concluded that:

1. The plastic coupling showed excessive bending under static load.

2. The plastic coupling showed excessive strength in impact testing.

3. When broken, the plastic coupling did not fracture cleanly.

4. The plastic frangible coupling is not equal to the standard metal frangible coupling, and does not meet the requirements, where applicable, of Advisory Circular 150/5345-48, FAA Drawing B-4904B, or of Military Standard MS17814(ASG).



76-38-1

FIGURE 1. PLASTIC AND STANDARD FRANGIBLE COUPLINGS

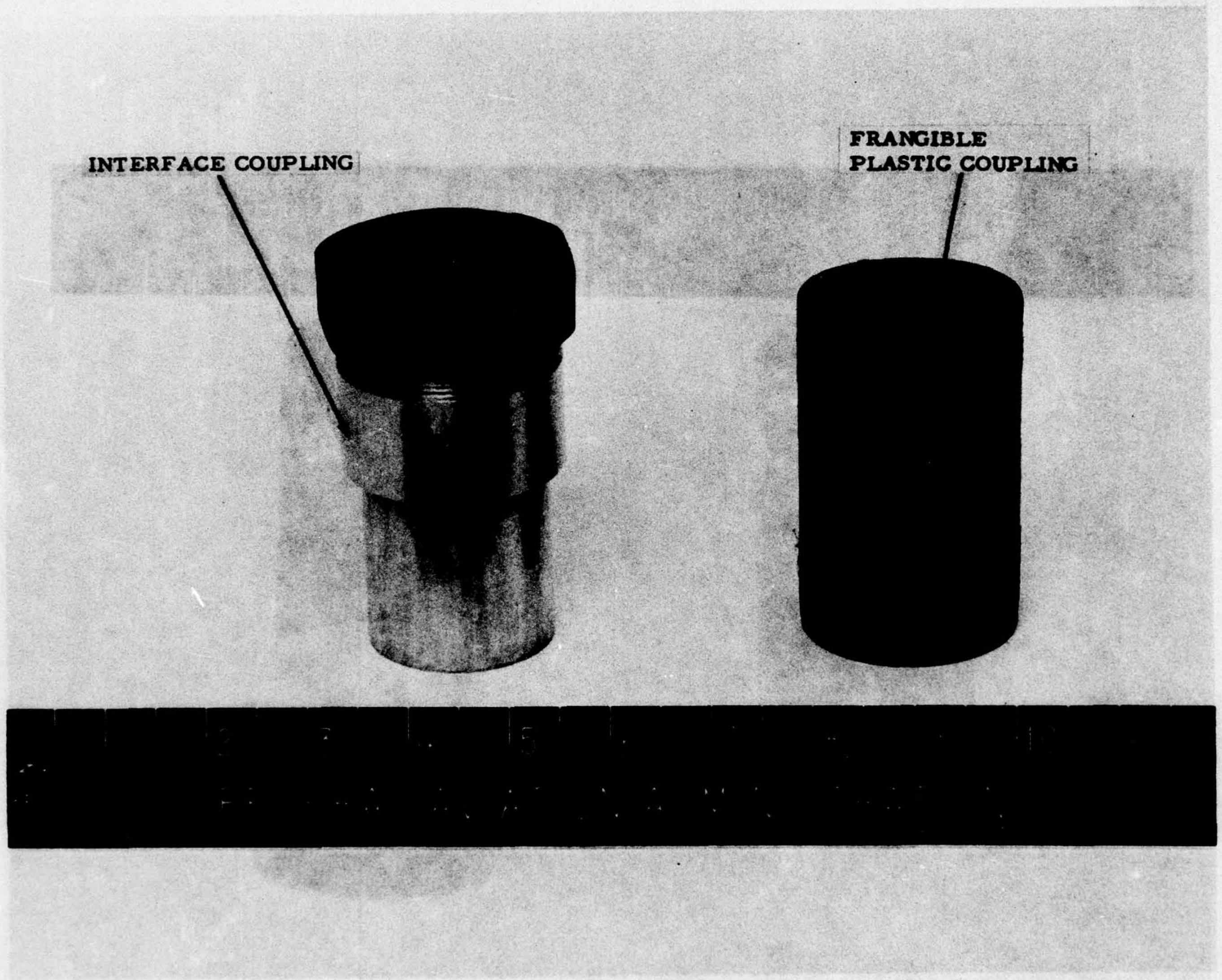


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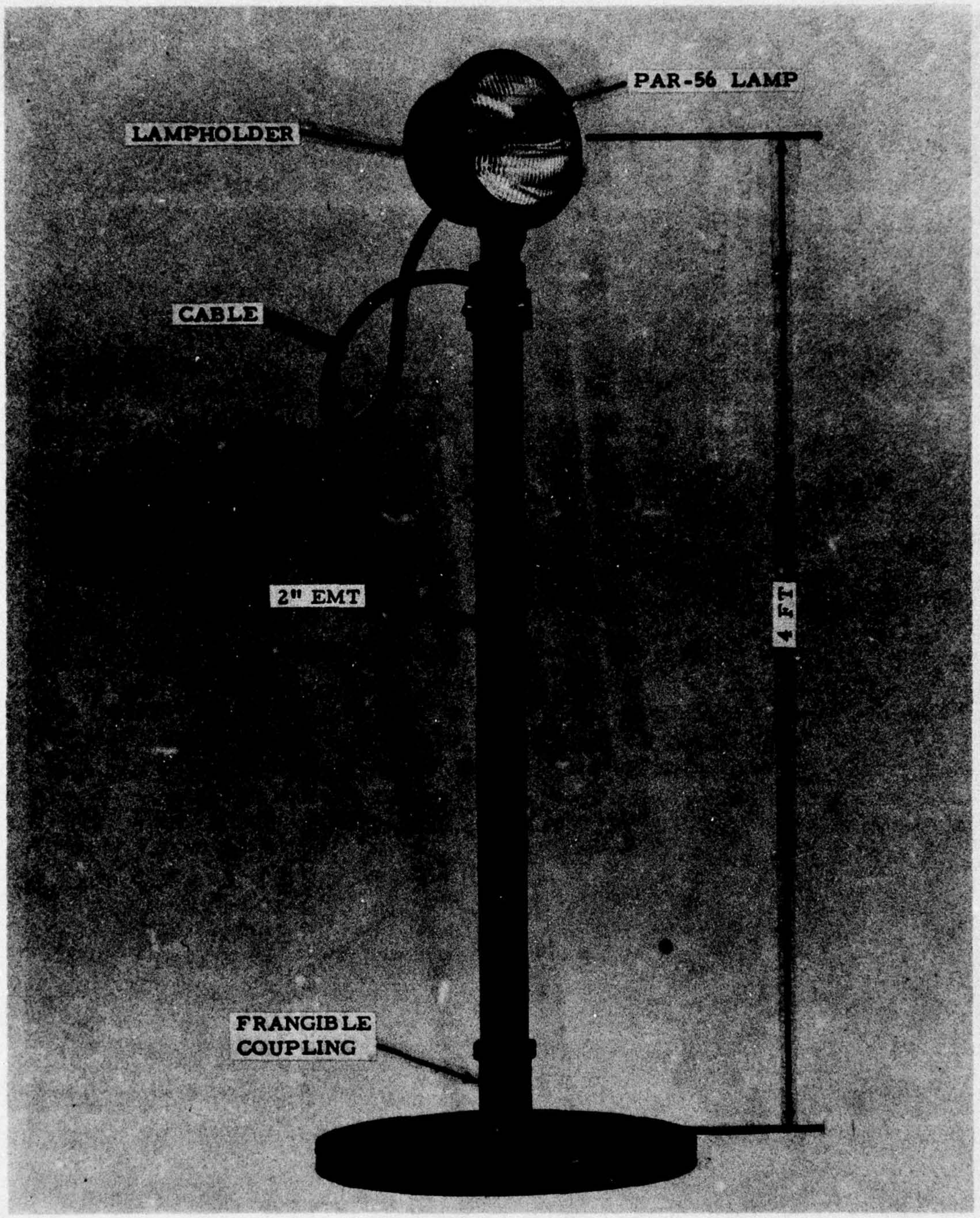
FIGURE 2. PLASTIC FRANGIBLE COUPLING SHOWING INTERFACE COUPLING



76-38-3

FIGURE 3. TYPICAL 4-FOOT PAR-56 LAMP ASSEMBLY

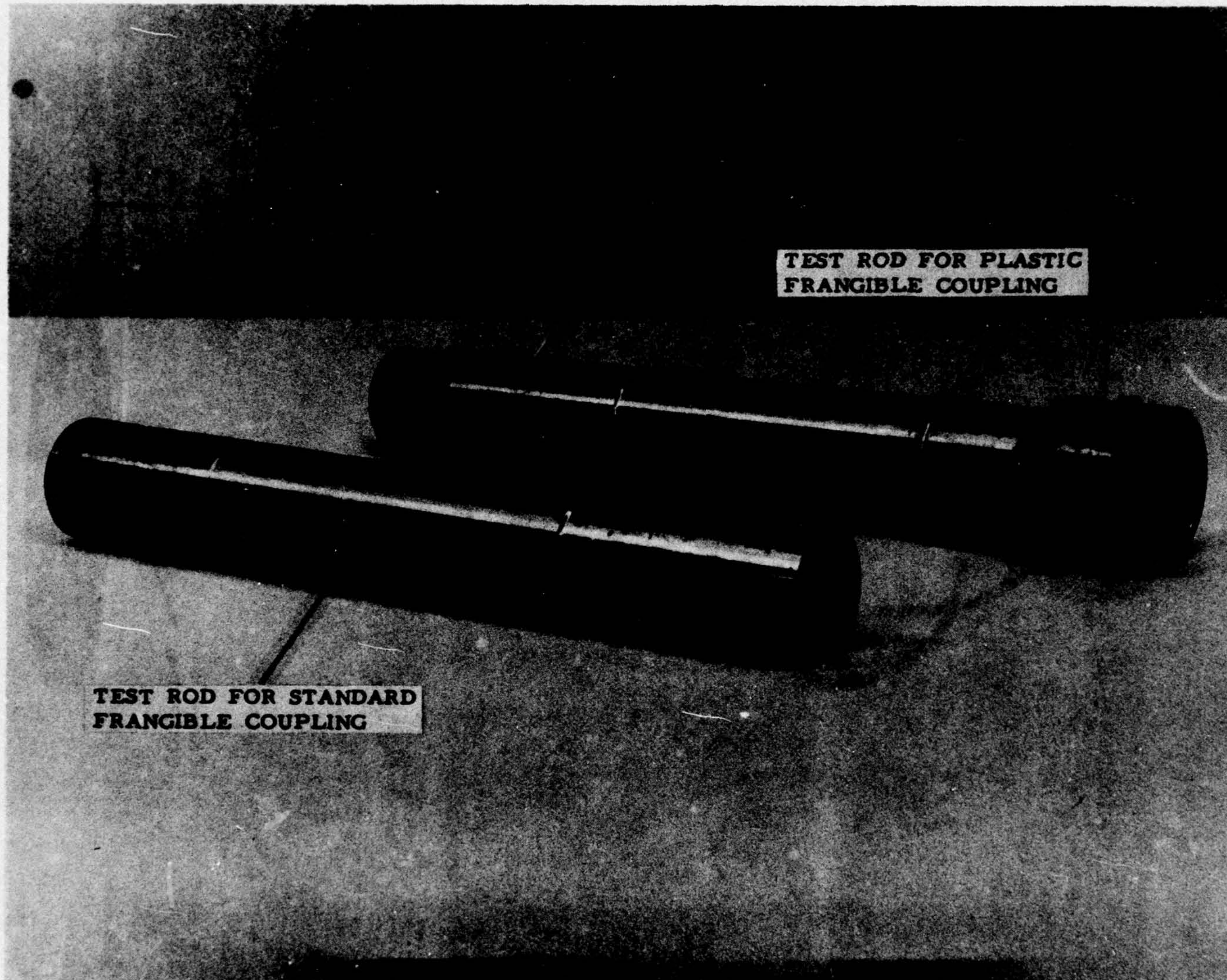
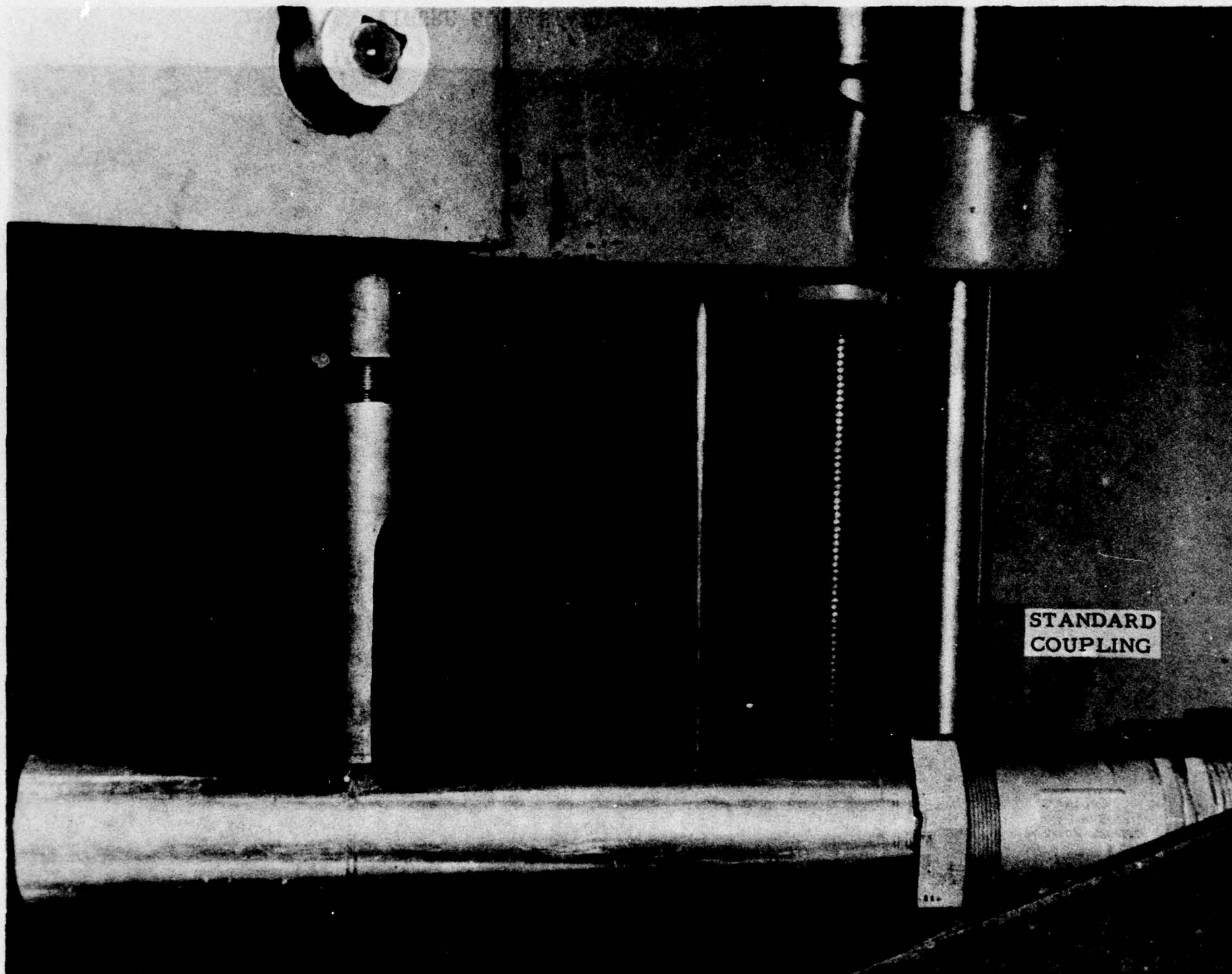


FIGURE 4. TEST RODS



76-38-5

FIGURE 5. STATIC TEST OF STANDARD COUPLING

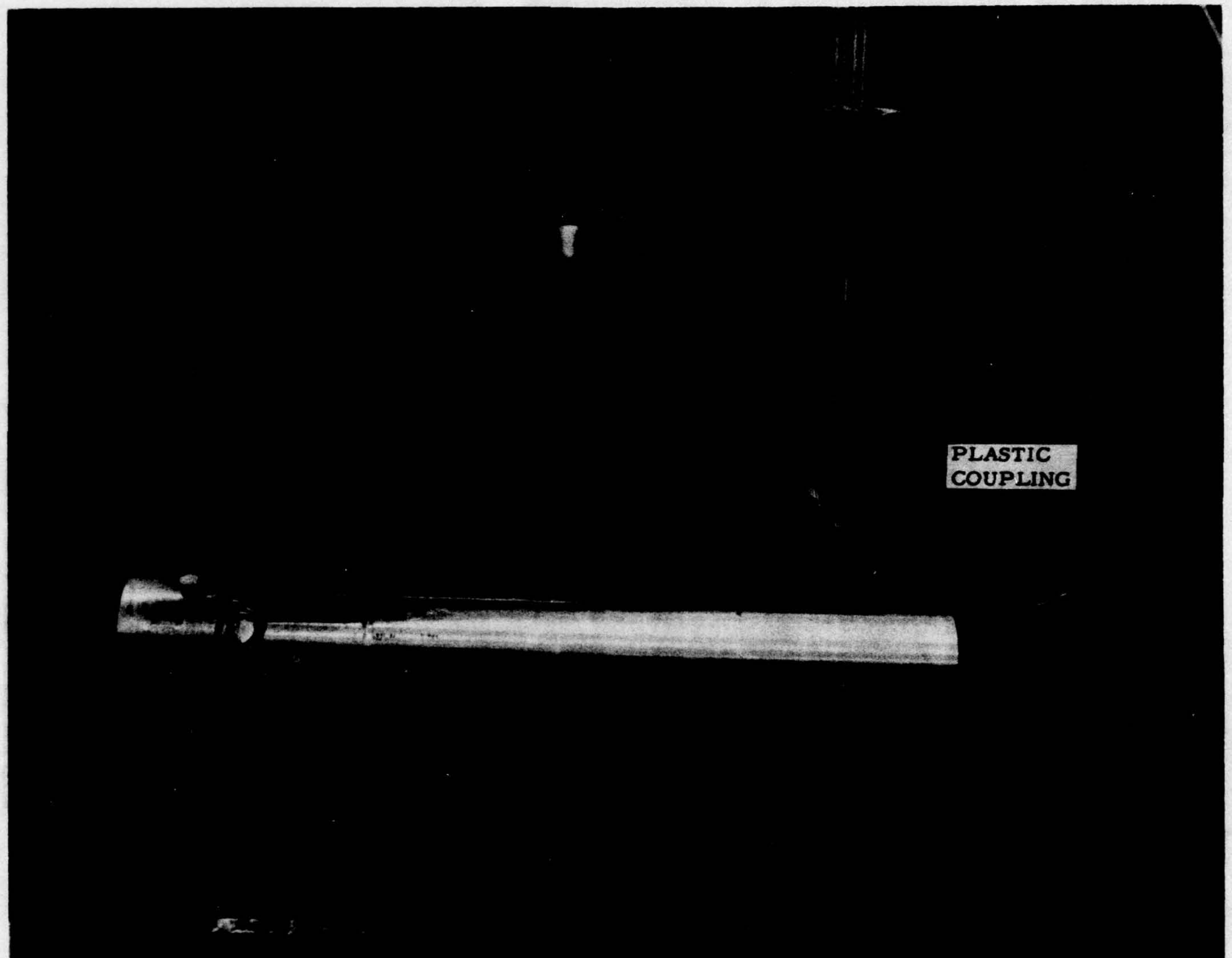


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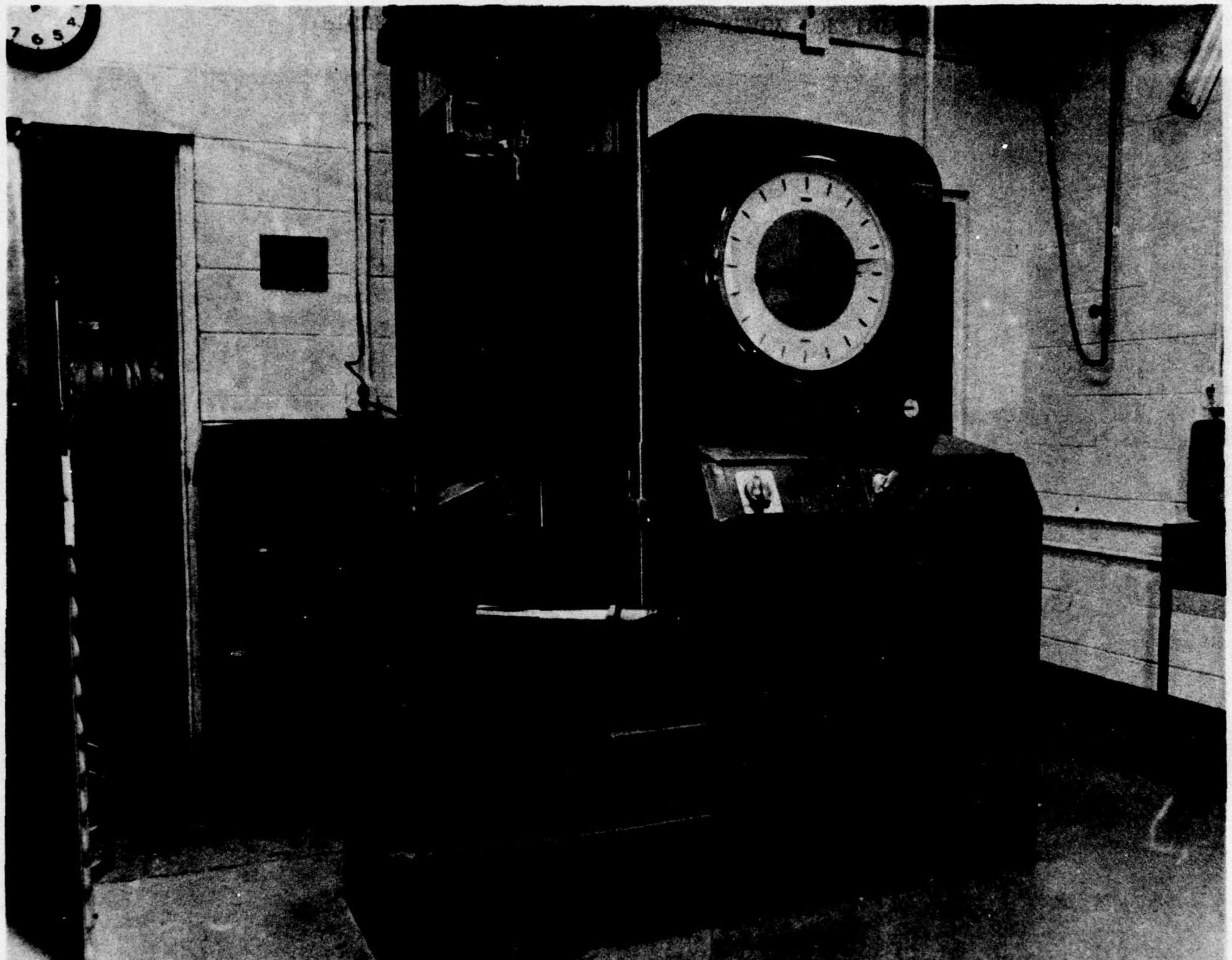
FIGURE 6. STATIC TEST OF PLASTIC COUPLING



76-38-7

FIGURE 7. RIEHLE TENSION/COMPRESSION TESTER

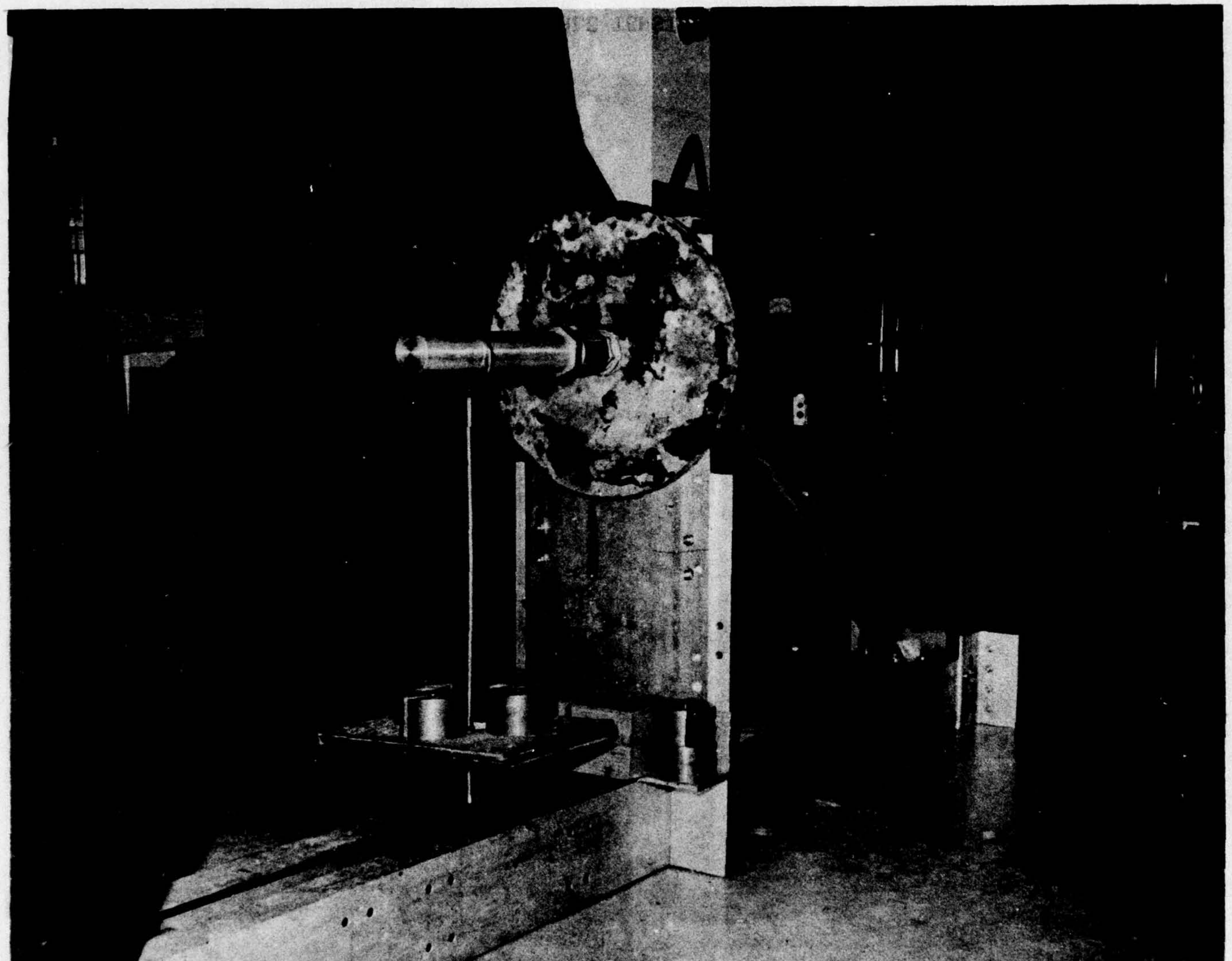


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FIGURE 8. STANDARD COUPLING READY FOR IMPACT TEST

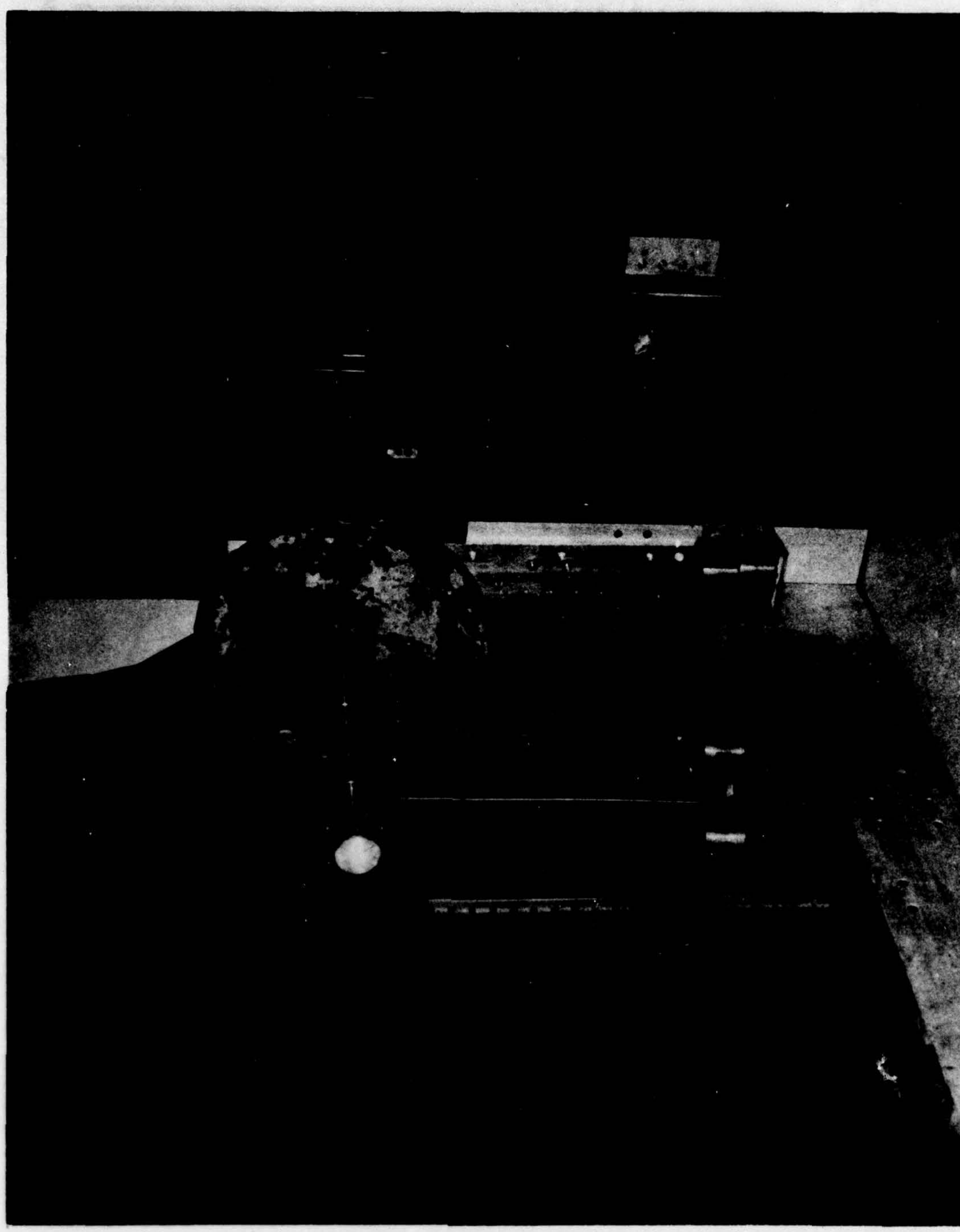

FIGURE 9. PLASTIC COUPLING READY FOR IMPACT TEST

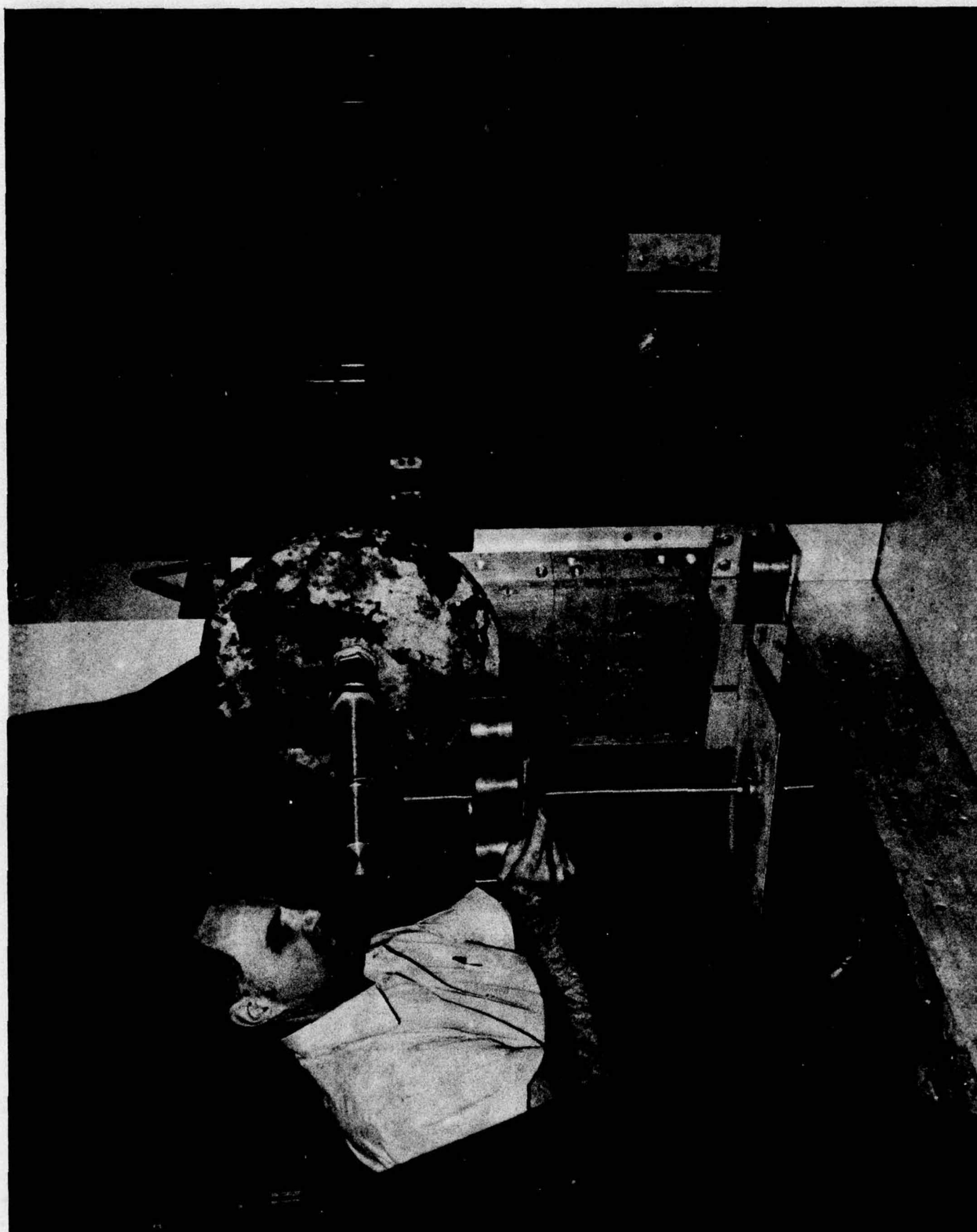

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FIGURE 10. WEIGHTS READY TO BE DROPPED 1-FOOT ONTO PLATFORM

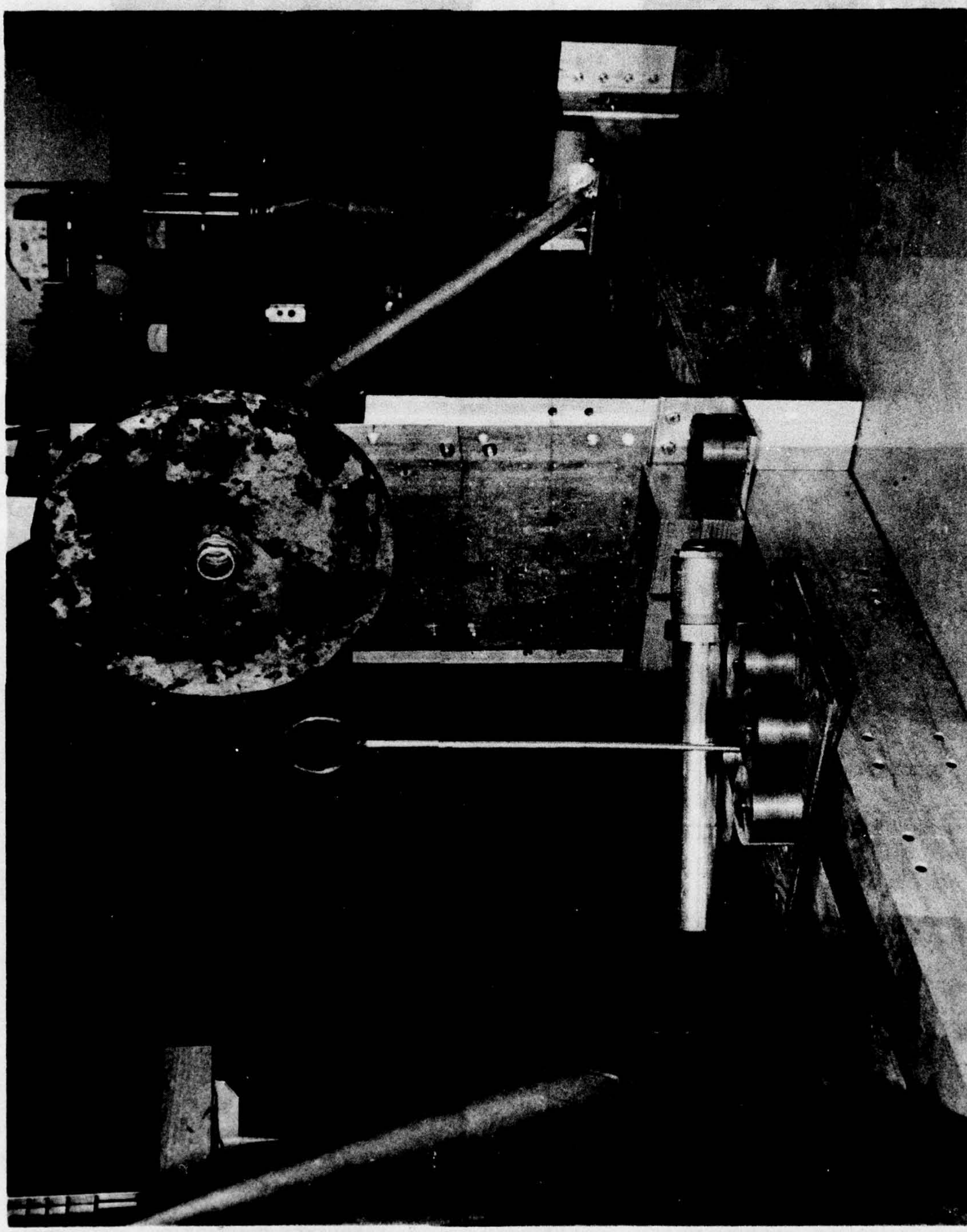
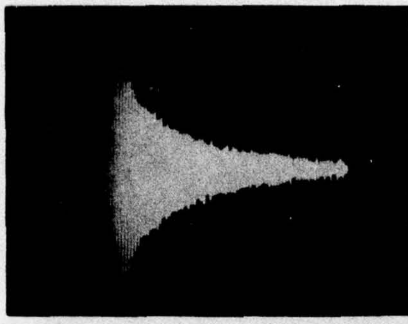


FIGURE 11. IMPACT TEST RESULTS SHOWING BROKEN FRANGIBLE COUPLING

STANDARD COUPLING



A. NATURAL VIBRATIONS

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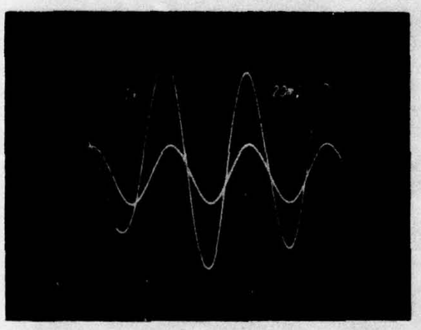
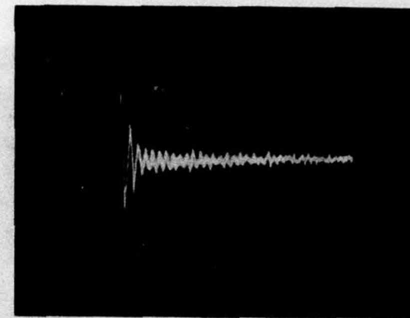
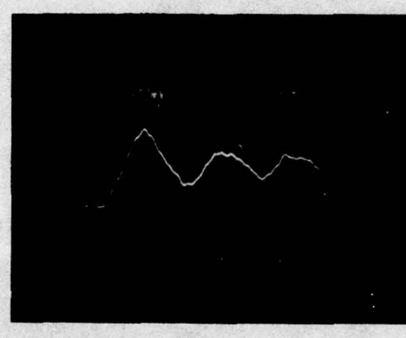


C. FREQUENCY COMPARISON

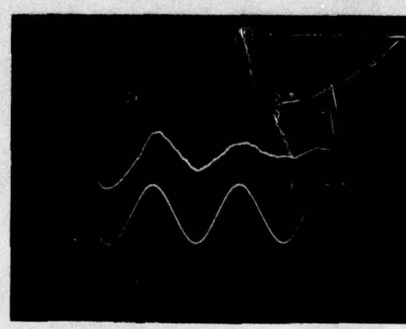
PLASTIC COUPLING



D. NATURAL VIBRATIONS



E. CENTER SECTION OF D



F. FREQUENCY COMPARISON

FIGURE 12. TYPICAL OSCILLATIONS FOR FRANGIBLE COUPLINGS

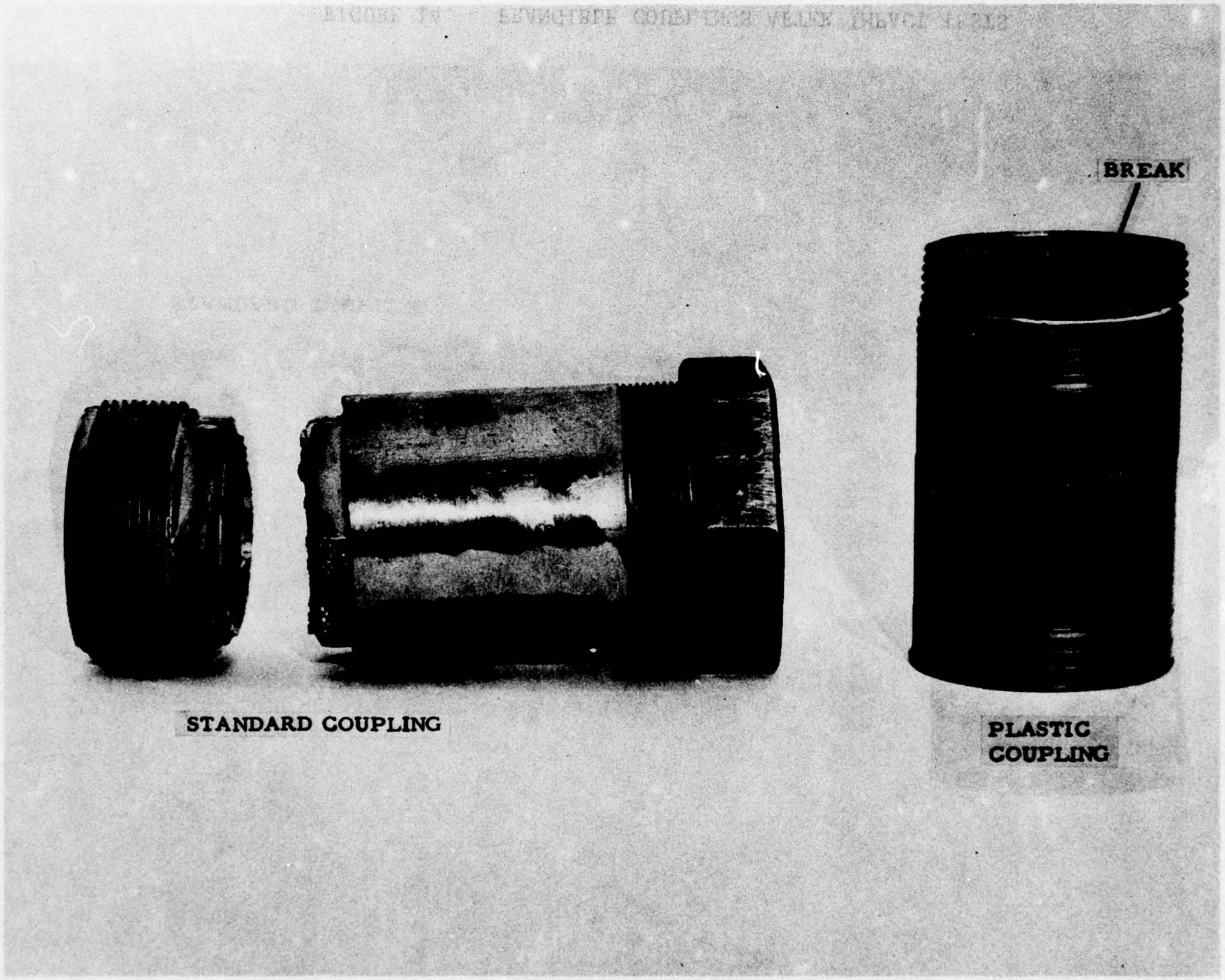


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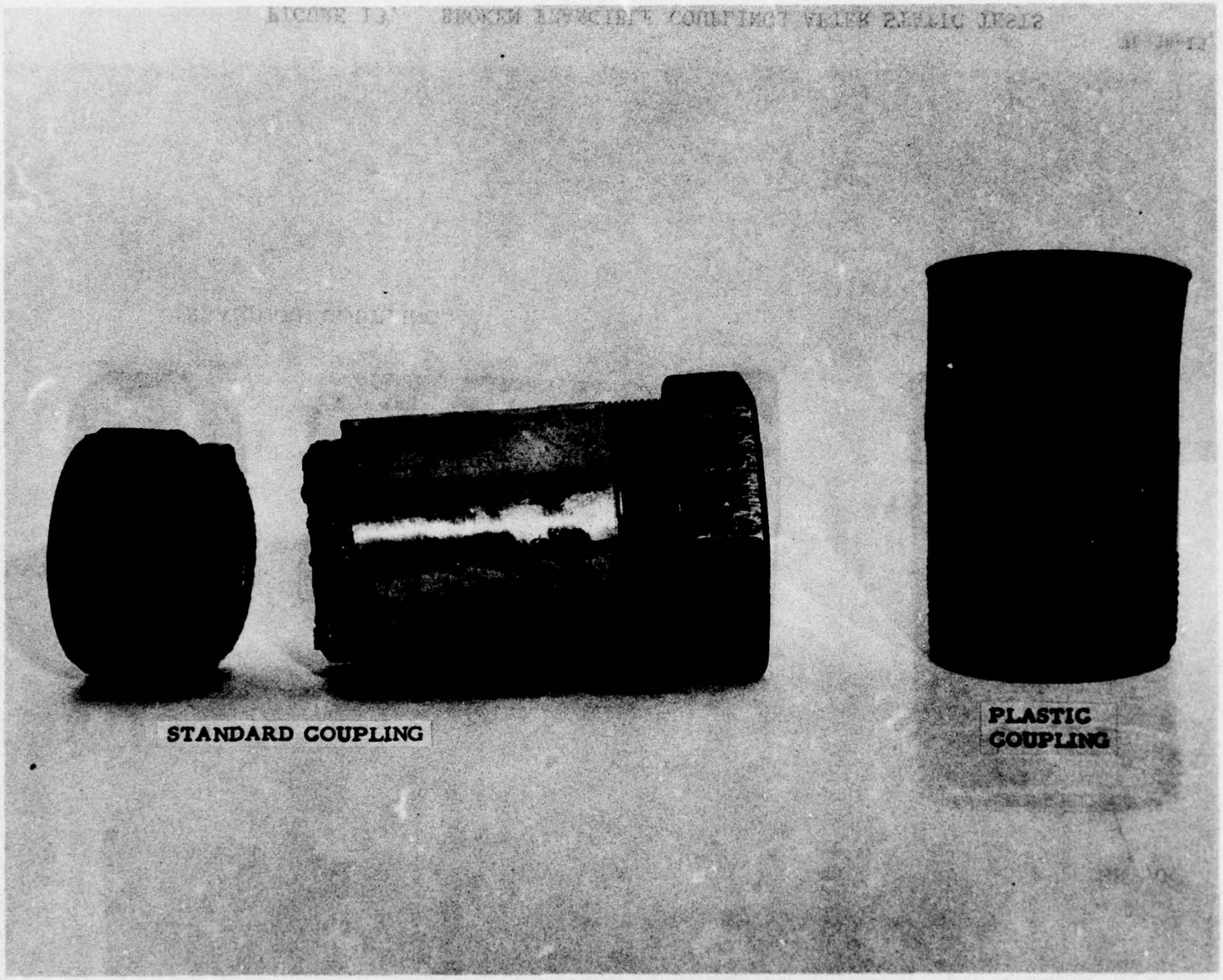
FIGURE 13. BROKEN FRANGIBLE COUPLINGS AFTER STATIC TESTS



76-38-14

FIGURE 14. FRANGIBLE COUPLINGS AFTER IMPACT TESTS